Saskatchewan
Agriculture
and Food

Final Report

Agriculture Research Branch
Saskatchewan Agriculture and Food

DEVELOPMENT OF A STRAW PARTICLEBOARD MANUFACTURING INDUSTRY IN SASKATCHEWAN

20000135

Executive Solutions Inc.

Saskatchewan

Saskatchewan Agriculture and Food
Industry Development Branch

3085 Albert Street
Regina, Canada
S4S 0B1

(306) 787-8526 Bus.
(306) 787-0271 Fax
(306) 539-8874 Cell.

mcarlson@agr.gov.sk.ca

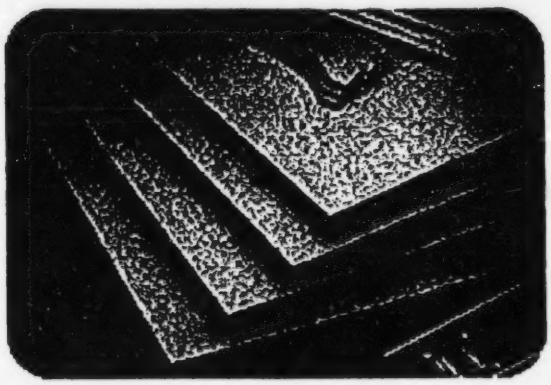
Maryellen Carlson
Director

Evaluation of Straw Particleboard Manufacturing

Prepared for

Saskatchewan Agriculture and Food

October 16, 2000



Executive Solutions

An Executive Source Company

Suite 401, 2201-11th Avenue

Regina, Saskatchewan, S4P OJ8

Notice to Readers

This report was prepared for Saskatchewan Agriculture and Food (SAF) through the services of an independent consulting company. While effort has been made to ensure the accuracy of this study SAF does not accept any responsibility for errors or omissions.

Saskatchewan Agriculture and Food's objective in having this report prepared was to bring together information to assist industry in assessing the viability of establishing straw particleboard operations in the province.

The underlying assumptions, used in the financial analysis, leads to the conclusion that only mid sized plants are viable. Because this report is limited in scope, the results from a different set of assumptions will generate a different outcome. No conclusions reached in this report should be construed as a recommendation by SAF. Each venture requires individual analysis and due diligence.

SAF encourages any organization considering the establishment of straw particleboard plant, of any size, to investigate such issues as, niche marketing opportunities, the capital cost of construction of a plant, operating costs of a plant, capacity of a plant, management and other factors to assess viability of an operation.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 2

A. FINANCIAL SUMMARY 5
B. INDUSTRY OPPORTUNITY 6

I. INTRODUCTION 9

II. PANEL BOARD PRODUCTS 11

A. PANEL BOARD PRODUCTS 11
B. PARTICLEBOARD STANDARDS 13
C. PANELBOARD MARKET 15
D. FOREST INDUSTRY 19

III STRAW PARTICLEBOARD MANUFACTURING 21

A. MANUFACTURING PROCESS 21
B. PLANT SUPPLIERS 24
1. COMPAK *24*
2. DAPROMA *25*
3. Hymmen *25*
4. Dieffenbacher/Schenck *25*
5. Siempelkamp *26*
6. Valmet Panelboard *26*
C. MDI RESIN 28
1. Huntsman Polyurethanes *29*
2. Dow Polyurethanes *29*
3. Bayer Polyurethane Division *29*
D. OTHER CONSIDERATIONS 30
E. SELECTING A PLANT SUPPLIER 31

IV CAPITAL COST PROJECTIONS 34

A. CAPITAL BUDGET ASSUMPTIONS 36

V. OPERATING BUDGETS 40

A. OPERATING COST ASSUMPTIONS 42

Disclaimer

This report did not include a detailed market study of the particleboard market. There may be niche market opportunities for manufacturers M-1 and M-2 grades of straw particleboard using manufacturing technologies not described in this report.

Executive Summary

The straw panelboard industry is an emerging sector with a checkered history. A number of plants have been built with serious cost overruns and numerous proposed projects in the US and Canada have been unable to secure financing. Nevertheless, for a number of sound economic and ecological reasons there remains a strong interest in developing an agri-fibre panelboard industry in North America. These reasons include:

1. Slowing the depletion of our forest resources by substituting renewable agri-fibre products for wood products. The growing worldwide movements towards Timber Certification to assure that customers do not purchase forest products that contribute to the degradation of forests. Timber Certification involves a chain-of-custody inspection from the stump in the forest through to the finished product and outlaws practices such as clear cutting. Recently it was estimated that the certification program covers 10% of North American forest products. Several large forest product customers (e.g., Home Depot and Ikea) have announced that they are going to refrain from buying lumber products that are produced from logs from old growth forests.

2. Wood fibre is becoming more expensive due to stricter environmental regulations and land claims by First Nation people, and harvest costs are escalating as logging moves into less accessible areas.

3. Weyerhaeuser, a giant forest company, is forecasting wood prices will rise during this decade due to a widening gap between timber supply and demand. This will increase the market opportunity for substitute products made from agri-fibres.

4. Reducing air pollution from burning straw and the CO^2 emissions that result from decomposing straw. And, agri-fibre panel products, such as straw particleboard, do not release the formaldehyde gas that is released by wood-based panelboard products.

5. Utilizing the vast and growing quantities of agriculture fibres (wheat, soybean, bagasse, etc.) that increase with ever-larger crop yields and new farming practices like zero-till farming.

6. Adding value to farm crops and bringing manufacturing jobs and tax revenues to rural areas.

7. Straw panelboard is a premium product because it is lighter and much more water-resistant than wood-based panelboard.

All agri-fibre particleboard plants use a similar manufacturing process, whereby an agriculture fibre (straw, bagasse, etc.) is blended with MDI resin and pressed under heat and pressure into a composite panel. There are some variations in the technology used, in manufacturing processes, and in the machinery used, but the core distinctions between plants is the quality of particleboard produced and their annual production capacities. These two factors are responsible for a wide variation in plant capital budgets and bottom line performance.

This study's evaluation of straw particleboard manufacturing focuses on plant economies of scale, product standards and manufacturing process for small, medium and large scale operations. The production capacities and financial analysis for the small-scale and medium-scale plants are based on one and two production lines. The large-scale plant analysis is for a single, continuous production line. This study is a conceptual analysis that compares the pros and cons of plants of different operating scales that also differ to some extent in their manufacturing equipment and processes. We surveyed each of the suppliers regarding their plant capacities and equipment costs, manufacturing processes and product specifications. Three companies provided detailed information. They were Compak Systems, DAPROMA and Valmet Panelboard. Several others indicated that they were no longer responding to detailed requests for information without some proof that a project had a good opportunity of being financed. We also reviewed several business plans and studies, interviewed various suppliers and conducted a thorough literature search.

While others may use this study as a map for developing an agri-fibre project, it should not replace the required rigorous preparation of a proper business plan and market study.

Exhibit 1 lists the companies that have the capability of designing and equipping a facility for manufacturing agri-fibre particleboard. Only Compak, DAPROMA and Bison have built agri-fibre plants in North America. Bison designed the large-scale Isobord plant operating at Elie, Manitoba, and has since been taken over by Valmet Panelboard. The Isobord plant is based around a Dieffenbacher continuous belt press. DAPROMA designed and supplied the equipment for the medium-scale PrimeBoard plant at Whapeton, North Dakota. Compak Systems is the equipment supplier for the WestGrain plant at Forestburg, Alberta. WestGrain is without a doubt the smallest available plant and the owners have recently announced that they are pursuing a financial restructuring and for the time being have ceased operations.

Exhibit 1: Suppliers of Engineering and Equipment for Agri-Fibre Particleboard Plants

	Small-Scale	Medium-Scale	Large-Scale
Production	two lines	two lines	continuous line
Annual Ouput	20,400 M^3	146,200 M^3	230,000 M^3
Capital Cost	$15 million	$57 million	$190 million
Board Standards	M-1, M-2	M-3	M-3
Suppliers	Compak Systems	DAPROMA Hymmen Valmet Panelboard	Dieffenbacher/Schenck Siempelkamp Valmet Panelboard

Source: consulting team

With the exception of Compak Systems and DAPROMA, the wood panelboard industry remains the focus of the above companies. Only Compak Systems concentrates exclusively on the agri-fibre industry, but in recent years DAPROMA has become an industry leader in agri-fibre manufacturing technology. Worldwide, Compak has six bagasse plants and five straw-based plants in operation. Company brochures say they have built a total of 16 plants. DAPROMA has put together six bagasse plants, three straw-based plants, a coca fibre plant and 17 wood panelboard plants.

According to industry insiders, the only profitable straw particleboard plant in North America is the PrimeBoard plant designed by DPROMA at Whapeton, North Dakota. This is consistent with our findings that demonstrate only a medium-scale plant can be profitable. PrimeBoard's one-line of production has a capacity of 51,000 M^3 of particleboard annually, but the plant has a design capacity to house a second line. The other two straw particleboard manufacturers, WestGrain, located at Forestburg, Alberta, and Isobord, located at Elie, Manitoba, are hoping to soon become profitable. The WestGrain plant is small-scale operation with an annual production capacity from two-lines of only 20,400 M^3. In contrast, Isobord is the straw-based industry giant with an annual particleboard capacity of 230,000 M^3. This output is more than 11 times the capability of WestGrain and more than four times the production capacity of PrimeBoard. The key process difference between Isoboard and the other two plants is its production line, which is designed around a giant belt press that accepts a steady stream of mixed straw fibre and resin adhesive to produce a continuous line of panelboard. WestGrain and DAPROMA use single and multiple opening presses, respectively. A mat former containing the blended straw fibre and MDI resin are fed into single opening press one at a

time and several at a time for the multiple opening press. After the pressing, the finished board or boards are expelled from the press for cooling, sanding and cutting.

The WestGrain plant is at present producing only underlay, M-1 and M-2 ANSI standard particleboard, which sells for prices that are in the order of 45% lower than the higher quality M-3 board produced by PrimeBoard and Isoboard. Furniture and cabinetry manufacturers demand M-3 quality particleboard.

A. Financial Summary

From our financial evaluation of the small-scale, medium-scale and large-scale plant options, it is readily apparent that only the medium-scale operation is financially viable and for two primary reasons. First, the capital investment per cubic metre of output is estimated at between $389 and $656 for the medium-scale plant depending on the number of production lines (Exhibit 2). The capital investment is $823 and $1,032 per cubic metre for large-scale and small-scale plants, respectively. In other words, the capital cost per unit of production for the most efficient two-line, medium-scale plant is about ½ of the cost of the large-scale plant and two-line, small-scale plant.

Second, our analysis shows that the production cost of $186 per cubic metre for the two-line, medium-scale plant is roughly ⅓ less than the cost of the large-scale and the two-line, small-scale operations. Under the assumptions that production is at full capacity and the entire output was sold at current market prices, only the medium-scale plant is able to show a return on equity. The return generated in this analysis was 20.5% based on an assumed equity investment of $28.4 million and a capital budget of $56.8 million.

Exhibit 2: Summary of Financial Analysis

	Small-Scale		Medium-Scale			Large-Scale
ANSI Standard	Underlay, M-1, M-2		M-3			M-3
Production Lines	1-Line	2-line	1-Line	1-Line	2-line	Continuous
Annual Capacity (M^3)	10,200	20,400	63,000	73,100	146,200	230,000
Capital Budget	$10,529,400	$14,667,376	$41,321,244	$37,078,650	$56,861,346	$189,222,969
Investment Cost per M^3	$1,032	$719	$656	$507	$389	$823
Production Cost per M^3	$376	$283	$246	$211	$186	$278
Gross Profit/Loss	-$2,276,613	-$2,664,534	-$1,211,654	$908,436	$5,443,250	-$12,491,297
After Tax Profit				$726,749	$4,354,600	
Return on Equity				3.9%	20.5%	

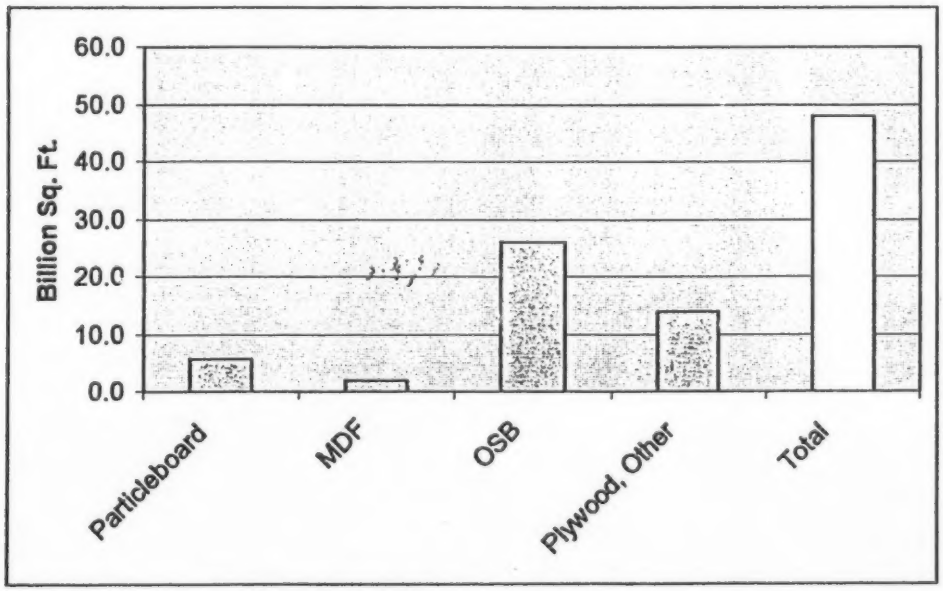
Some of the equipment suppliers may take issue with our financial analysis as being too conservative in its assumptions. Compak Systems, for example, have said they can build a

two-line plant for as little as $13 million, which is about $1.6 million less than our capital projection for a small-scale plant. DAPROMA provided our study team with a $50 million budget for a medium-scale, two-line plant, but we felt their estimate did not adequately reflect all the startup costs such as working capital and interest on debt during construction. Even though the original budget for the large-scale Isobord plant was reported to be as low as $150 million, it is now speculated that the project has ballooned to more than $225 million.

B. Industry Opportunity

The market for structural and non-structural panelboard products is enormous and growing each year (Exhibit 3). In 1999, total North American shipments were estimated at more than 48 billion square feet (3/4-inch basis). Particleboard shipments were estimated at 5.84 billion square feet, an increase of 5.1% over 1998. The demand is expected to keep rising throughout the 2000s. Straw particleboard currently accounts for about two percent of the particleboard market. Medium Density Fiberboard shipments were another 2 billion square feet in 1999 and demand is projected to continue to increase.

Exhibit 3: 1999 Panelboard Shipments for North America (¾ inch basis)



Source: Resource Information Systems Inc., www.resourceinfo.com

North American structural panel production reached 40.2 billion square feet in 1999, and OSB made up 65% of this output. OSB is used extensively in the construction industry and is often used as a substitute for plywood. More than 70% of wall, floor and roof sheathing is done with OSB. As a structural product, OSB sells for much higher prices than particleboard.

In 1999, OSB prices (FOB plant) averaged around C$560 per thousand square feet, which is roughly 40% higher than the price for M-3 particleboard at $402 per thousand square feet. According to industry insiders, OSB prices should continue to rise in the future unless there is a slow down in the North American economy. Throughout the 1990s, the demand for OSB has been increasing while the demand for plywood was shrinking. OSB is produced from virgin timber and the price of logs is forecasted to keep on rising for both environmental and economics reasons. This translates into a bright future for any agri-fibre plant that could produce a straw-based OSB to meet ANSI standards.

While several firms provide manufacturing equipment for straw particleboard, no one has been able to supply a manufacturing process to produce a structural panelboard made from an agri-fibre. Recently, DAPROMA announced a breakthrough saying they have produced a straw-based oriented strand board (OSB) in their pilot plant in Sweden. In straw particleboard manufacturing, the straw is put through a hammer mill where it is fiberized. But to manufacture OSB, the straw must be split lengthwise. Split straw is much stronger than the fiberized preparation used in particleboard. This split straw can then be mixed with a resin adhesive and the resulting blend can pressed under heat into OSB using a process very similar to particleboard manufacturing. DAPROMA says they have developed machinery to split straw economically. The Alberta Research Council has also registered worldwide patents for straw splitting technology and a process to manufacture what they are calling Oriented Structural StrawBoard. They have licensed the technology to a firm in China and are looking to sign similar agreements in North America.

According to DAPROMA, the capital and operating costs for a straw-based plant with one-line dedicated to particleboard and one-line dedicated to OSB are very comparable with the two-line, medium scale plant analyzed in this study. If this were the case, then one would expect the profitability and return on investment to be much higher than those shown in this study's financial analysis.

The future of a Saskatchewan agri-fibre panel industry depends on meeting head-on several key challenges and opportunities.

1. The most efficient plant size requires an investment in the range of $55 to $60 million. This means attracting an equity investment of between $25 and $30 million. While several rural communities have shown an interest in financing a

project, they do not have the resources to support this level of financing. In the past, rural communities have found it difficult to raise more than $1 to $1.5 million in local project financing. While some monies for a project are anticipated to come from various government investment funds, a project would still have need of a large private investor or investment consortium. The most likely sources conceivably are a forestry company, a furniture manufacturer like Ikea, or maybe a panelboard wholesaler/retailer like Home Depot or Federated Coop. Obtaining the OSB straw technology rights for North America might be a useful strategy for attracting equity.

2. OSB production would significantly enhance the viability of a straw panelboard plant. But the new technology has not been demonstrated under full-scale manufacturing conditions, which means at this stage higher risks. However, these risks can be mitigated by painstaking project management and supplier guarantees.

3. Any agri-fibre project in Saskatchewan needs to explore all value-added opportunities. For example, a laminating line could be added to the straw particleboard manufacturing process for a cost of $2.5 to $5 million. One business plan reviewed during the course of this study showed revenues would increase by more than $20 million annually from laminating and selling half of the particleboard output of a two-line, medium-scale plant. Moreover, a laminating line could be the catalyst for attracting a furniture manufacturer to Saskatchewan. Another value-added opportunity to consider is an automated panel saw operation that custom cuts panel dimensions to fill odd-sized orders. The ability to supply odd-size panels commands premium prices from furniture manufacturers.

In conclusion, long-term market forces support the development of an agri-fibre panelboard industry in North America. Saskatchewan has the attributes to be an excellent manufacturing location. The next step is to develop a business/market plan based on the construction of an efficient, medium-scale plant that incorporates new technologies to produce OSB and other value-added opportunities. A strategy is also needed to overcome equity financing hurdles.

I.

Introduction

Groups in Saskatchewan have approached Saskatchewan Agriculture and Food (SAF) and other government agencies about the feasibility of developing a provincial straw particleboard manufacturing industry. Entrepreneurs in Manitoba, Alberta and North Dakota have built manufacturing plant and there are interest parties in several other US jurisdictions that are actively seeking project financing or are conducting feasibility studies.

SAF commissioned this study is to identify which of the available manufacturing technologies and processes would be most appropriate for the successful development of a straw panelboard industry in Saskatchewan. This evaluation is to:

1. Describe the main suppliers of equipment and process design services. These companies are suppliers of turnkey plants. The equipment can come from several suppliers and manufacturers.

2. Provide an overview of the particleboard market.

3. Identify particleboard grades and standards.

4. Describe the manufacturing process and equipment components.

5. Analyze capital and operating costs the manufacturing options.

6. Identify value-added opportunities

It was not practical for this study to try and develop a detailed design for a straw panelboard plant and expect each of the equipment suppliers to submit proposals for a hypothetical plant. In fact, several of the equipment suppliers refused our requests to provide detailed information without a detailed request for proposal and there was proof that project financing was available. Over the past several years, these suppliers have had numerous requests for proposals and equipment quotations only to find out after a considerable expenditure of time and money that the project would not be going ahead.

This study does not try to evaluate the technologies, engineering capabilities and design capacities of suppliers. All of the equipment suppliers use very similar technology that has

been proven in the marketplace. But there are variations amongst suppliers in the quality and amount of the straw particleboard produced due to differences in manufacturing processes and in the capacities of their equipment. Accordingly, there is a considerable divergence capital and operating costs. These aforementioned differences are the focus of this evaluation.

This report was a collaborative effort by Executive Solutions, DCW Project Consulting Inc, and Virgin Solutions Inc.

II.

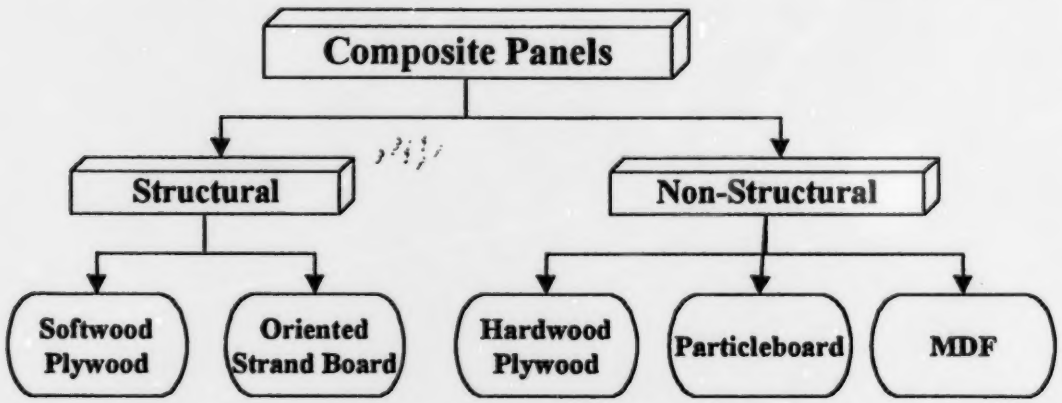
Panel Board Products

The purpose of this section is to provide the reader with an overview of panelboard products, and the various grades and standards of particleboard. There is also a general explanation of the panelboard and particleboard markets. Currently, the agri-fibre panelboard manufacturers are only capable of producing straw or bagasse particleboard. This is expected to change because of technological advancements that can split straw in the straw preparation stage of the manufacturing process.

A. Panel Board Products

The following is a description of the types of panelboard products. Figure II-1 shows that panelboard is categorized into structural and non-structural uses. All of these panelboard products have traditionally been manufactured by combining wood fibre and urea-formaldehyde adhesives.

Figure II-1: Types of Panel Board



Approximately 2 percent of the particleboard manufactured in North America is produced using agricultural fibres, primarily made from wheat straw. DAPROMA and the Alberta Research Council both claims that they have developed new technologies to manufacture a

straw-based board that will satisfy the standards for oriented strand board. DAPROMA says it has actually produced a straw OSB in its pilot plant in Sweden. The Alberta Research Council has worldwide patents on equipment for splitting the straw and for the components of the manufacturing process. They have licensed their technology to a plant that is being built in China and are looking for a commercial partner in North America. Discussions have taken place with two companies, but they are still very open to other interested parties.

The following is a description of the types of panelboard.

Particleboard – Particleboard is a non-structural panel usually made from wood particles of various sizes that are bonded together with a urea-formaldehyde adhesive under heat and pressure. It is used in furniture, cabinetry, floor underlay, stair treads, counter tops and subflooring.

Particleboard can also be made using various agricultural-based fibres such as cereal straws. Because straw has a wax coating, it will not bind using urea-formaldehyde. The binding resin used in straw particleboard is known as MDI (diphenylmethane diisocynate). MDI makes straw particleboard more water-resistant than wood particleboard and straw particleboard weighs less than wood particleboard. And, there are no gas emissions like the formaldehyde that is released by wood particleboard.

Medium Density Fiberboard (MDF) - MDF is made from refined wood fibre that has been digested (cooked) to remove the pulp and then bound together with urea-formaldehyde under high heat and pressure. MDF is a high quality panel because it has a uniform consistency resulting from the uniform distribution of wood fibres throughout the board. MDF normally commands a premium price over particleboard because it is better suited for machining and edge treatment. Typical applications include furniture, cabinetry, moulding and millwork.

Hardwood Veneer and Plywood – Hardwood veneer and plywood share many of the features of softwood plywood, but because of higher manufacturing costs they are used primarily for decorative rather than structural purposes. The main uses are decorative wall paneling, furniture and cabinetry.

Oriented Strand Board (OSB) – OSB is structural panel made from wood strands, flakes or wafers bonded with exterior-grade adhesives (phenol-formaldehyde or isocyanate) under intense heat and pressure. The product is manufactured in layers with the strands in each layer aligned at right angles with each other. OSB is widely used in the construction industry to sheath walls, floor and roofs.

Both the Alberta Research Council and DAPROMA Inc. are working on processes to manufacture an Oriented Structural Strawboard (OSSB). The technology involves splitting the straw and bonding the split straw in layers that are at right angles with each other.

Softwood Plywood – Softwood plywood is built up of veneer piles. The thickness and orientation of the plies determine the performance of the panel. The veneer sheets are united under high temperature and pressure with a waterproof adhesive (phenol-formaldehyde) to meet stringent exterior applications. Softwood plywood is used extensively as roofing and flooring materials, siding, wall sheathing and preserved wood foundations.

B. Particleboard Standards

Particleboard is produced in North America under a voluntary product standard prescribed by the American National Standards Institute (ANSI). ANSI A208.1-1993 classifies particleboard by grade and use (see Exhibit II-2). Industrial users of M-2 and M-3 are the main target markets for the straw particleboard manufacturers. The M-3 grade commands the highest prices and it is a layered board that is made with the finer straw fibres on the outside surfaces of the board. The result is a smooth surface when the board is sanded. A homogeneous board is not able to satisfy the M-3 standard. A homogenous board has a surface containing course fibres and the surface pits when it is sanded or is machined. Therefore, it has very limited use in furniture or cabinetry manufacturing.

Exhibit II-2: ANSI A208.1-1993 Grades and Uses

Grade	Letter Designation Meaning	Use
M-1	Medium density (640-800 kg/m^3)	Underlay, shelving, furniture
M-2	Medium density (640-800 kg/m^3)	Underlay, shelving, furniture, cabinets
M-3	Medium density (640-800 kg/m^3)	Shelving, cabinets, furniture, countertops, stair treads, moudlings
M-S	Medium density (640-800 kg/m^3)	Cabinets
H-1, H-2, H-3	High density (above 800 kg/m^3)	High Density Industrial
LD-1, LD-2	Low density (less than 640 kg/m^3)	Door Core
PBU	Underlayment	Non-Structural Flooring Underlayment
D-2, D-3	Manufactured home decking	Home Decking

Source: Composite Panel Association Buyers and Specifiers Guide, www.pbmdf.com

The ANSI standard covers physical, mechanical and dimensional characteristics and outlines test methods, inspection practices and methods of identification. It is important to note that a consistent minimum board density is mandatory to comply with the standards. Exhibit II-3 provides the main requirements for M-1, M-2 and M-3 grades of particleboard.

Exhibit II-3: Grade Requirements for Medium Density Straw Particleboard

		Thickness Tolerance							
	Length & Width mm(inch)	Panel Avg. from Nominal mm(inch)	Variance from Panel Avg. mm(inch)	Modulus of Rupture	Modulus of Elasticity	Internal Bond	*Screwholding* Face	Edge	Formaldehyde Maximum Emmissions
Grade	(+/-)	(+/-)	(+/-)	N/mm^2(psi)	N/mm^2(psi)	N/mm^2(psi)	N (pounds)	N(pounds)	(ppm)
M-1	2.0(0.080)	0.250(0.010)	0.125(0.005)	11.0(1595)	1715(250200)	0.40(58)	NS	NS	0.30
M-S	2.0(0.080)	0.250(0.010)	0.125(0.005)	12.5(1813)	1900(275600)	0.40(58)	900(202)	800(180)	0.30
M-2	2.0(0.080)	0.200(0.008)	0.100(0.000)	14.5(2103)	2250(326300)	0.45(65)	1000(225)	900(202)	0.30
M-3	2.0(0.080)	0.200(0.008)	0.100(0.004)	16.5(2393)	2750(398900)	0.55(80)	1100(247)	1000(225)	0.30

NS-not specified

Source: Composite Panel Association Buyers and Specifiers Guide

The follow provides a definition of some of the requirements specified in Exhibit II-3.

- **Screwholding** -A measure of the force required for withdrawing a screw directly from the face or edge of the board stated in pounds (lbs.).
- **Modulus of Elasticity (MOE)** - A measure of the board's resistance to deflection or sagging when loaded as a simple beam. Value stated in pounds per square inch (psi).
- **Modulus of Rupture (MOR)** - An index of the maximum breaking strength of the board when loaded as a simple beam. Value stated in pounds per square inch (psi).

Only straw particleboard manufactured to M-3 standards has excellent machining characteristics. To produce a board with good machining characteristics, it is essential that the straw fibre used in the manufacturing process be prepared with the proper length and particle size. This preparation is dependent on many factors, such as the capabilities of the fibre milling equipment, controlling moisture content, fibre screening and so on. Consistency of the fibre is an absolute must and it is imperative the resin is applied in such a way to ensure all particles receive a resin coating. This ensures proper cross bonding of each particle and fibre. Failure to obtain this kind of bonding results in particles being torn away during the surface sanding and machining processes, thus creating minute depressions on these surfaces. In the application of melamine laminates these depressions and inconsistencies will telegraph through and appear on the surface of the finished

product. Because of the shinny nature of the melamine surface, deformities are obvious and are unacceptable to the marketplace.

C. Panelboard Market

In 1998, 5.84 billion square feet (¾ inch basis) or 10.3 million cubic metres of non-structural particleboard was shipped by plants in the US and Canada. The estimate for 1999 is also 5.84 billion square feet. Exhibit II-4 shows particleboard shipments increased 5.1% over 1997. If the price of all grades of particleboard averaged $300 per thousand square feet, then the market for particleboard in 1998 in 1999 was in the neighbourhood of $1.8 billion. By 2009, it is predicted the particleboard market will be 7 billion square feet.

Exhibit II-4: US/Canada Particleboard Shipments Increased 5.1% in 1998

	1998	1997
	Shipments (M^3)	
Door Core	407,339	377,629
Flooring	853,189	854,707
Industrial (furniture, cabinets, etc.)	8,925,725	8,399,742
Other	142,500	196,143
	10,328,753	9,828,221
Canada Shipments	2,200,936	21.3%
US Shipments	8,127,818	78.7%

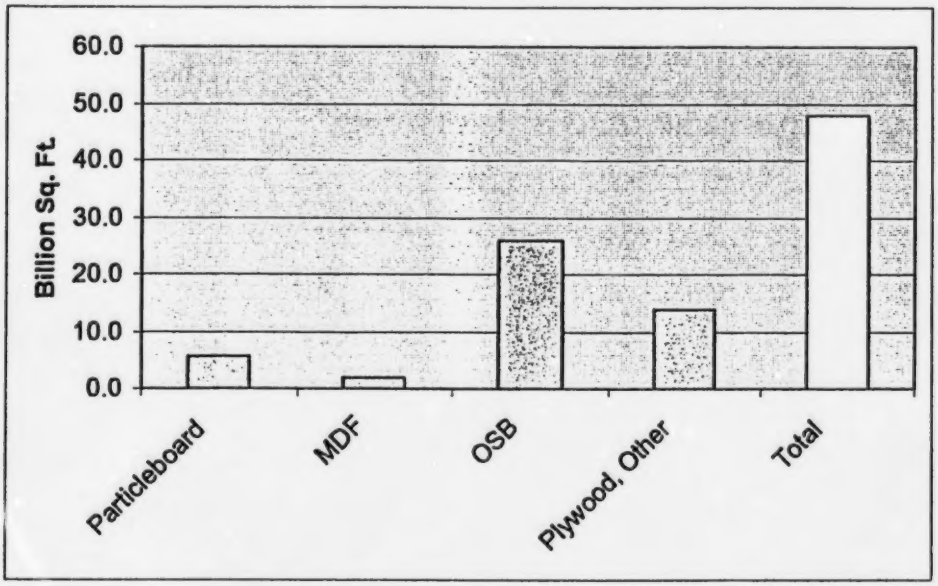
Source: Composite Panel Association, 1998 Annual Shipments Report, www.pbmdf.com

Virtually all of the agri-fibre particleboard production in Canada and the US is sold into the industrial market and is made to an M-3 standard. A small amount of M-1 and M-2 grades of particleboard was produced at Forestburg and sold as non-structural underlay flooring.

Exhibit II-5 shows the total panelboard market has been estimated at 48 billion square feet for 1999. The structural segment of the market was approximately 40.2 million square feet (3/8" inch basis) and orient strand board made up 65% of this output or 26.1 billion square feet. This means there is tremendous opportunity for an agri-fibre OSB, if the new manufacturing technologies can duplicate the standards of the wood-based product.

Based on an average price of $500 per thousand square feet, the structural panelboard market would be $24 billion annually, and the OSB segment of the market would be worth an estimated $15.6 billion and growing. In recent years, OSB demand has been growing while plywood demand is shrinking. By 2009, OSB production is expected to top 30 billion square feet.

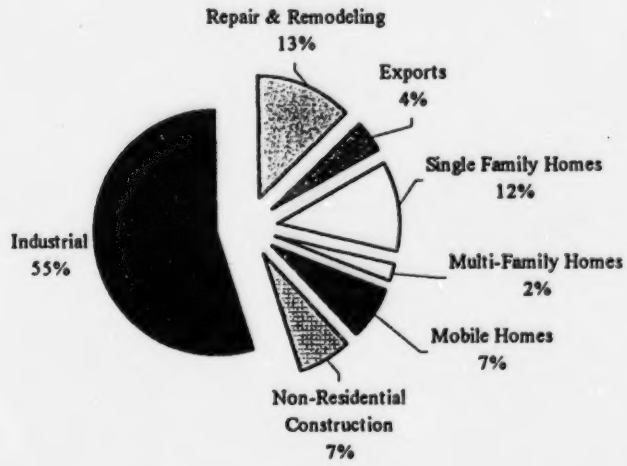
Exhibit II-5: 1999 North American Panelboard Shipments (3/4-inch basis)



Source: Resource Information Systems Inc., www.resourceinfo.com

Exhibit II-6 breaks down the particleboard market by use. It also shows that Canadian manufacturers made 21.3% of the shipments, which represents 1.2 billion square feet or 2.2 million cubic metres of particleboard. In 1998, 55% of particleboard shipments in the US were for industrial use. Most of the industrial use is by furniture manufacturers. Household furniture manufacturing accounted for 28% of all particleboard shipments and another 20% was used in office furniture. The second largest end-user of particleboard in the US is the residential construction industry, which accounted for 34% of all shipments. By definition, residential construction includes mobile home manufacturing and companies involved in repair and remodeling work. Exhibit II-6 provides a breakdown of particleboard shipments by end-use in the US for 1998.

Exhibit II-6: 1998 Shipments of Particleboard by US End-Use



Source: Composite Panel Association, 1998 Annual Shipments Report, www.pbmdf.com

The straw particleboard manufacturing accounts for around 2% of the total US/Canada particleboard output. Almost all of this product is M-3 grade and is used in the industrial sector of the market. If 1998 particleboard shipments are taken as the base year and it is assumed that the market growth will continue at 5% annually, then the consumption of straw particleboard reach 250,000 m^3 in 2000. Currently, the three main manufacturers of straw particleboard have a combined annual capacity of 310,000 m^3. The Isoboard plant located at Elie, Manitoba, is by far the largest agri-fibre plant in North America with an annual capacity of 230,000 m^3. The PrimeBoard plant at Whapeton, North Dakota is the next largest with an annual output of 53,000 m^3 from its single production line. The small-scale Compak plant at Forestburg has recently started production and its full production capacity is 20,400 m^3 annually from two production lines.

Exhibit II-7 lists the current manufacturers of straw particleboard. The two Kansas plants are too small to have a noticeable impact the market.

Exhibit II-7: Annual Capacity of Straw Particleboard Manufacturers (¾-Inch Basis)

		Capacity (M^3)
Kansas	Naturall Fibre Board	5,000
	Prairie Forest Products	11,000
North Dakota	PrimeBoard Inc.	53,000
Alberta	Compak Forestburg	20,400
Manitoba	Isoboard Enterprise	230,000
		319,400

Source: various sources, including Composite Panel Association, 1998 Annual Shipments Report

There are several particleboard manufacturers using agriculture fibres other than cereal straw. A recent report says plants are being constructed or planned using by-products of food crops such as rye grass, rice straw, soy stalks and bagasse.[1] The Acadia Board Company has started production in New Iberia, Louisiana. At full capacity, this plant will annually use about 45,000 tonnes of bagasse from sugar cane processing to produce 30,000 M^3 annually. The board is made using a similar process as straw particleboard manufacturing and will be sold into the same markets.

Some planned agriculture fibre projects are shown in Exhibit II-8. Except for Acadia Board Company, they are all to be straw particleboard plants. Some of these projects have been in planning for several years and are still looking for financing. The Acadia Board Company has recently started production in Louisiana. The AgriFibre Industries plant at Wanham, Alberta ran short of funds and never started production. It has recently been bought and it is believed that it may be turned into a wood-based plant. Perhaps, because there were past difficulties in securing a suitable supply of straw. A company called Fieldboard International is currently looking for financing for a proposed strawboard plant at Killam, Alberta. The Parkland plant is planned for Kamsack, Saskatchewan. Harvest Board International has the most ambitious plans. It wants to build three large plants in Kansas, North Dakota and Alberta. One of these projects, the Goldboard plant slated for Thornhill, Alberta, recently moved their offices from Edmonton to Finley, North Dakota. A local farmer cooperative in Finely is trying to attract plant financing for a plant to be managed by Goldboard. Home Depot has said it will help find the financing and will

[1] *Evaluation of Manufacturing Fiberboard with Ag-Fibers,* Donald Lengel, www.agrifibertechnology.com, June 2000.

purchase product. Phenix BioComposites is also looking for financing for a future straw particleboard plant to be constructed near Mankota, Minnesota.

Exhibit II-8: Planned Agri-Fibre Particleboard Projects

	Capacity (M^3)
Acadia Board Company	33,000
AgriFibres Industries	130,000
FieldBoard International	50,000
Parkland	25,000
Goldboard Ltd.	345,000
Phenix Manufacturing Co.	71,000
Harvest Board Intl.	248,000
	902,000

Source: Composite Panel Association, 1998 Annual Shipments Report

D. Forest Industry

Historically, the world demand for wood and paper products follows world population growth. The combined wood and paper products market in the US is now US$230 billion annually. For wood products, including panelboard, North American is the largest market segment followed in order by Europe, Asia, Russia and Latin America.

Weyerhaeuser, one of the world's largest forestry companies, has projected that the growing demand for wood products will add to the demand for timber by about 1.4% per annum until the end of the decade. By 2010 the world demand for logs will exceed 2 billion cubic metres. The annual North American share is expected to be about 850 million cubic metres. While timber demand is increasing, the worldwide supply of raw softwood and hardwood timber is falling largely due to the environmental and other pressures to reduce the harvest from public lands. By 2010, Weyerhaeuser predicts the timber supply will decline by 9% in North America to about 700 million cubic metres. This will leave a timber shortfall of about 150 million cubic metres annually.

Because of the rising demand for wood products and decline of timber supply, the forestry industry is predicting escalating wood and panelboard prices over the decade. This has two important consequences for the agri-fibre industry:

1. The demand for engineered wood products (OSB, particleboard, MDF, etc.) will continue to grow, partly because the forestry industry needs to use timber more efficiently and has is being forced to use wood from smaller trees.

2. Rising prices for wood products over the next decade is going to encourage the development and use of substitute products made from none-wood materials and this will enhance the market opportunity for agri-fibre panelboard products.

Unfortunately, these forecasted trends for wood products have not caused the forest industry to begin producing products made from agri-fibres. To combat the widening gap between timber supply and demand, the forestry companies are instead focusing their efforts on initiatives such as tree farming, new harvest technologies to reduce waste, massive reforestation and the development of new manufacturing technologies to use timber more efficiently. Interest is an agri-fibre alternative is unlikely to become serious until it is demonstrated that agri-fibre products can be manufactured to meet the structural board standards required in the large construction and industrial markets. The most rapidly growing part of these markets is the demand for OSB. Another major market breakthrough opportunity for agri-fibre products is like to be in paper products. This segment of the forestry industry is facing the same harvest, environmental and supply challenges as the wood products segment. On a per capita basis, North Americans now use 750 pounds of paper annually.

III

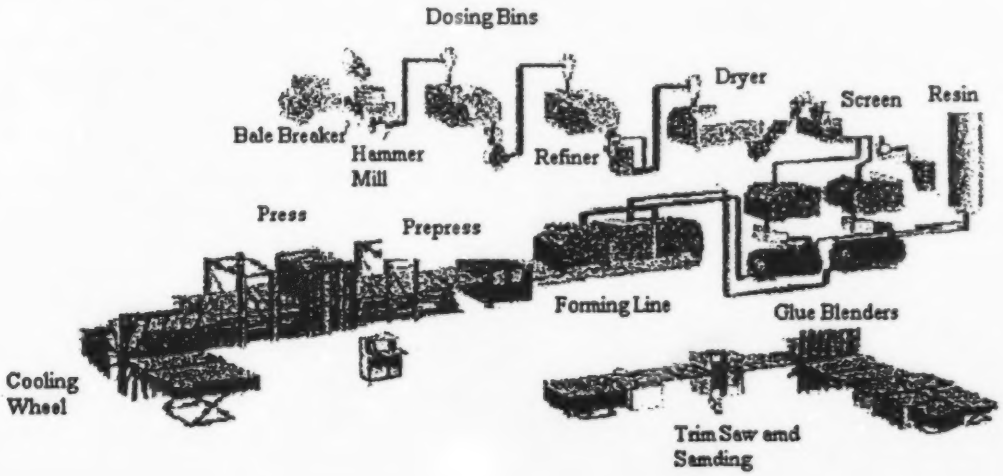
Straw Particleboard Manufacturing

This section provides an overview of the straw particleboard manufacturing process and provides background information on the main suppliers and manufacturers of equipment and MDI resin. Differences in equipment and the manufacturing processes are pointed out in Exhibit III-2.

A. Manufacturing Process

The basic steps in straw manufacturing particleboard and MDF are in actual fact generic to the industry (Exhibit III-1). First the straw or wood fibre is size reduced and then it is mixed with an MDI binder resin (straw or other agri-fibre) or a formaldehyde adhesive (wood) in a mat former. The mat former is then sent to a heat press where the panel board is formed. After curing, the board is sanded and cut to the desired dimension.

Exhibit III-1: Generic Straw Particleboard Manufacturing Process



The following describes the steps in the agri-fibre manufacturing process. There is no difference in the basic technology of the various equipment suppliers. Each is based on blending fiberized cereal straw with resin and then pressing this material under heat and pressure.

1. **Straw Supply** – Wheat, oats, barley and rye straw can be used in the manufacturing process described in this report. The equipment can be adjusted to use any of the cereal grain.

2. **Bale Braking and Straw Preparation** - The process begins with the transport of straw bales from the storage area to an in-feed conveyor system, dumping the bales into a bale breaker. The twine is removed and the straw length is reduced to a 1" to 3" length.

3. **Straw Cleaning** - the chopped material is fed into a separator to remove dirt, stones, grain and other unsuitable material. Magnets are also appropriately placed in the separator to remove any foreign ferrous (steel) material.

4. **Hammer Milling** - The cleaned material is now hammered for further particle size reduction to approximately 3/4" to 1". At this point, moisture may be added to increase the yield and reduce dust fines.

5. **Fiberizing** - The hammer milled material is fed over a separator, fines are conveyored directly to a dryer, courser material fed to a fiberizer, then transported to the dryer. The fiberized material and fines are referred too as "furnish". If a layered board is being manufactured then adjustments to the fiberizer mill will be required to adjust the percentage of fine fibres.

6. **Drying** - The furnish is indirectly heated and tumbled in a rotating dryer to reduce moisture content to an appropriate level for resin blending. Spark detection and fire suppression systems are incorporated into all areas of high fire ignition risk. Alternatives to rotation type dryers may be recommended as an engineering preference by the turnkey company designing and supplying the manufacturing line.

7. **Screening** - The furnish is separated by screening it into "fine" and "course" materials that are then conveyored into their respective dry silo bins. Oversized material is sent over to a second refiner for further fiberizing. Dust is conveyored to a dust silo and may be used as fuel for the boilers, discarded to landfill sites or recycled back into the manufacturing system to become part of the particleboard. This latter option is not recommended because dust particles absorb higher amounts of resin.

8. **Resin Blending** – The surface (fine) and core (course) furnish are taken from their respective bins and are passed across continuous weigh scales to their respective blenders. These continuous weight signals interact (through the PLCs) with the positive displacement resin pumps to ensure the delivery of a pre-determined application percentage of the resin. The correct amount of resin is pumped into high-speed atomizers within the rotating blender providing an even resin distribution into the fibre. A wax solution also may or may not be added at this point. In some instances, fine and course materials are not separated and batch mixing is used if a homogeneous board is being manufactured. The resin calculation is then based on the batch weight.

9. **Mat Formers** – WestGrain produces a homogenous board. DAPROMA and Isobord are layered boards. When a homogeneous board is produced, the fine and course straw fibres are not separated and layered, but they are mixed together to provide a balanced consistency throughout the board. When manufacturing a layered board (fine material on the top and bottom surfaces with courser fibre in the core) a series of mat formers position the board's surfaces and core layers of the mat onto moving caul plates. In a layered board the top and bottom surfaces contain the finer fibres for a smooth finish that offers a superior base for machining and laminating. The core is made up of the stronger course fibres. Each company supplying a turnkey manufacturing line will have his or her own mat former or will recommend an off-the-shelf purchase.

10. **Pre-Press** - The mat is compressed to reduce thickness to allow entrance into hot press. This contributes to a reduced cycle time in the hot press and thus produces a higher manufacturing efficiency. After Pre-Press a weight check is performed to ensure pre-determined density specifications are met.

11. **Hot Pressing** - The hot press can be a single opening or a multi-opening press. (a) In a single opening press a single large mat is conveyored on a caul plate into the press. Upon completion of the pressing cycle, it is conveyored out of the press and then trimmed and cross and/or longitudinally cut as required to accommodate sanding. (b) In a multi-opening press the caul plates carrying the mats are conveyored and stacked into an elevating loading rack on the input side of the press. When the press opens, they are simultaneously placed into the press. After pressing the boards are ejected and board and caul plates are separated and the caul plates are returned for reloading. The boards are transferred into a cooling wheel and afterwards are stacked. (c) With a continuous belt press, the mats are fed continuously into the press. The press is programmed to travel at a preset speed to ensure the pressed board is totally cured when it leaves the press. Upon exiting the press, the board is cut to the

appropriate length and then sanded. Each type of press has an operating program that automatically controls the conveyor speed, pressing time, and the temperature and pressure of the press. Thermal oil or steam provides heat energy to the platens in the press. A mold release is required with the use of MDI resin to prevent the board from adhering to the press. In some instances, the resin manufacturer will add the mold release agents into the resin. There are other products such as surfactants or oleander soaps that can be sprayed onto caul plates or upper mat surfaces. For a continuous press operation a paper protective barrier is used to sandwich the mat as it enters the press.

12. **Finishing** - After 24 to 48 hours of cooling and normalizing, the boards are loaded into a combined sanding and sawing operation. The boards are accurately and precisely sanded to the specified thickness and surface finish, and are they sawed to the required size.

13. **Warehousing** – The final steps involve the proper labeling, bundling and stacking to await order processing and shipment.

In addition to the above, there is a thermal-oil boiler that provides the heat energy for drying and pressing. It can be fueled by natural gas and/or waste dust collected from the sander and during the manufacturing process. Throughout the manufacturing process there has to be in-process quality assurance checks and laboratory equipment testing of the physical properties of the finished product. This is essential to maintain a high and consistent board quality.

B. Plant Suppliers

Following is a brief description of the main suppliers (design and equipment) of straw particleboard plants. Compak is the only supplier of a small-scale capacity plant with a capacity of up to 20,400 M^3 annually with two production lines. DAPROMA and Hymmen construct medium-scale plants with up to 150,000 M^3 output for two-lines. The other suppliers offer only large-scale production capacity plants in excess of 200,000 M^3 annually.

1. COMPAK

Compak Systems was formed solely to develop a commercially viable process to make high quality agrifibre panelboard. Their headquarters are located at Britannia Works, Lincolnshire, England. The development of the agri-fibre manufacturing process at Compak Systems has been ongoing since the late 1970's, with the first

plant being commissioned in 1990. In total, 16 Compak Systems plants have been sold worldwide.

The Compak process combines agricultural residue fibre and/or wood flake with a polymeric MDI binding resin to produce composite panels. Technology development has been pursued with three main fibre groups, namely cereal straw, sugar bagasse, and wood flakes. Other agriculture crops and grasses can also be used as raw materials. Compak System production facilities are classed as small-scale, multi-line operations.

2. DAPROMA

DAPROMA is headquartered in the City of Karlstad, in the heart of Sweden's southern forest industrial region. DAPROMA is a relatively young Company, founded in 1986. Nevertheless, its specialized staff of engineers and technicians each have 15 to 30 years of experience in plant design, engineering, construction and plant erection. They purport to have in-depth knowledge of manufacturing and production of wood-based and lignocellulosic boards and panels. DAPROMA has been involved in various MDF and particleboard projects worldwide, using wood and bagasse as the raw material. The most recent developments by DAPROMA have been the design, construction and erection of turnkey systems using cereal grain straw as raw material in the production of straw particleboard and OSB using diiocyanate (MDI) as the binder. Their production facilities are medium sized plants.

3. Hymmen

Hymmen GmbH is located in Bielefeld, Germany, with their North American office, Hymmen International Inc., located in Atlanta Georgia. They provide a turnkey strawboard production facility utilizing their design of a double band continuous press. Their production facility is classified as a medium sized plant.

4. Dieffenbacher/Schenck

Dieffenbacher GmbH & Co. is located in Eppingen, Germany, with their North American offices, Dieffenbacher North America, located in North York, Ontario. They offer planning of complete panel board manufacturing lines, from forming to finishing for particleboard, OSB and MDF, with their press being the centerpiece. They say that their team of experienced service and commissioning engineers guarantees that assembly and start-up are performed in the shortest possible time; with a priority placed on follow-up by reliable customer service. Great importance is attached to personnel training. For customers' specific requirements, three types of presses and press line systems are available: (i) the Conti-Power System -CPS- with

a continuously operating double press; (ii) the multi-opening cycle press system: and (iii) the single opening cycle press system. Their designed panel board production facilities are classified as large sized plants. Isobord uses a Dieffenbacher press.

5. Siempelkamp

The Siempelkamp Group is located in Krefeld, Germany. Siempelkamp specializes in the construction of machinery and plants for producing panel-shaped materials. Siempelkamp provides the complete design, supply, assembly and start-up of individual line components as well as complete production facilities. Everything is provided in close collaboration with the member companies of the group, including machinery and equipment which define the process as well as the control and process control systems. Siempelkamp's single source concept provides design and engineering, manufacture of the components, assembly, interface management, start-up and optimization. The range of products offered by the Siempelkamp group includes (i) complete plants for the production of particleboard, MDF and OSB; and, (ii) engineered wood products. Their panel board production facilities are classified as large sized plants. Worldwide, they have built more than 350 plants for the wood-based materials industry.

6. Valmet Panelboard

Valmet Panelboard (a member of Metso Corporation) is located in Sundsvall Sweden, where it has a panelboard pilot plant and research laboratories. Valmet resulted from the combination of Sunds Defibrator, Bison, Kusters and Kvaerner. As a result of these companies coming together, Valmet can now provide the entire manufacturing process for MDF, particleboard and OSB. The company developed a modular approach to panelboard production with a simple and straightforward process control where all unit processes are fully integrated. Yet, each of the modules can be custom-tailored to meet specific requirements in a smoothly operating plant. Valmet designed facilities are classified as large sized plants.

Valmet have recently announced a working agreement with PrimeBoard, Whapeton, North Dakota, to join forces to provide the market with large-scale strawboard solutions. However, the PrimeBoard plant was designed and built by DAPROMA, not Valmet. Bison (now part of Valmet) designed the Isobord plant in Manitoba.

All of the above suppliers will provide guarantees regarding plant output capacities and manufacturing product specifications. Equipment will come with warrantees and service plans. Consumable parts (belts, saw blades, etc.) are kept in inventory.

Exhibit III-2 summarizes the process followed by each of the equipment suppliers with the exception of Siempelkamp. Siempelkamp did not respond to requests for information and has yet built a straw-based particleboard plant. For each of the steps in the process indicated by an X, the equipment supplier provides a piece of equipment. Where there is no X, the equipment supplier does not include that step of the process in their plant design. For example, Compak produces only a homogeneous particleboard.

Exhibit III-2: Plant Equipment and Manufacturing Process Comparison

Process Step	Compak	Dapropma	Hymmen	Diefenbacher/ Schenck	Valmet Paneboard
Straw Preparation		X	X	X	X
Cleaning		X		X	X
Hammer Milling	X	X	X	X	X
Fiberizing		X		X	X
Drying		X		X	X
Screening		X		X	X
Resin Blending	X	X	X	X	X
Mat Formering	X	X	X	X	X
Pre-Press	X	X		X	X
Multiple Opening Press	X	X			
Single Opening Press	X				X
Continuous Press			X	X	
Caul/Board Separation					X
Cooling Wheel		X		X	X
Discharge Stacker	X	X	X	X	X
Multihead Sander		X	X	X	X
Inspection Station		X		X	X
Panel Cutting/Trim	X	X	X	X	X
Fuel (Dust)		X			
Fuel (Natural Gas)	X	X	X	X	X
Fuel (Duel)		X			
Layered Board		X		X	X
Homogeneous Board	X	X	X		
Board Thickness-1/4"	X	X			
Board Thickness-3/8"	X	X	X	X	X
Board Thickness-1/2"	X	X	X	X	X
Board Thickness-5/8"	X	X	X	X	X
Board Thickness-3/4"		X	X	X	X
Board Thickness- 1"		X	X	X	X
Board Thickness- 1 1/8"		X			X
Board Thickness- 1 1/4"		X			X
Baord Thickness - 1 1/2"					X

Source: Review of materials and quotations supplied by equipment suppliers

C. MDI Resin

Cereal straw is coated with a natural wax, so bonding together straw fibres requires a potent binder. MDI, an acronym for diphenyl methane diisocynate, works well because it seeks out and reacts with both the moisture in the fibre and the hydroxyl groups that make up the fibre. The result is a chemical bond that possesses high strength and is resistant to extreme moisture. The formaldehyde-based resins used in wood composite panels form a mechanical bond by attaching themselves to the wood fibres and then hardening. These mechanical bonds are destroyed by exposure to water causing the wood panels to swell much more than an agri-fibre particleboard bonded with MDI.

An advantage of MDI is its ability to bond a variety of crop by-products such as cereal straw, bagasse and many other agricultural materials. The propensity of MDI to form bonds is of such a degree that it bonds with metal. This is a disadvantage as it causes a sticking of the top and bottom surfaces of the particleboard mats to the metal surfaces of the hot press. Thus, release agents have been developed by the MDI manufacturers to prevent such sticking when they are applied to the outside surfaces of the board.

MDI is four to five times more expensive than the formaldehyde adhesives used to bind wood fibres. But the application rate of MDI is lower at between 3 to 5% relative to the weight of the straw. For commercially acceptable bonding, wood composite products require adhesive application rates of 6 to 12%. MDI is sprayed into the blender in the form of small droplets to assure even distribution as it is mixed with the straw fibre. During hot pressing the droplets are melted and spread out to form a bond between neighboring straw fibres. MDI is predominantly converted into inert, soluble, stable cross-linked polyureas in the presence of water. Since it requires water for bonding, it is possible to enter and exit the press at higher moisture content requiring a significantly lower straw-drying requirement.

Even though rising petroleum should push up the cost of MDI, prices for MDI have been dropping for several years due to an increase in world production capacity. MDI is used in a host of applications, including the production of foam for use in furniture and the soles of running shoes. While a tonne of straw typically costs between $40 and $50, a tonne of MDI at current prices is around $2,800 delivered. An agri-fibre panelboard plant using 100,000 tonnes of straw annually would expect to pay between $4 to $5 million for straw. With an application rate of 3.5% of straw usage, the resin cost for of 100,000 tonnes of straw would be in the order of $8 million. Consequently, it is critical to have an efficient manufacturing process that minimizes the resin application rate. Some engineers believe they can get the resin application rate as low as 2.5%. Isobord is reported to have a high usage rate in excess of 5%.

The are at least a dozen manufacturers of MDI around the globe. The three main suppliers are described below.

1. Huntsman Polyurethanes

Huntsman is an International Organization, employing over 2000 people in 41 locations across the world with their American head office being located in West Deptford, New Jersey. Their Rubinate® binder is used as the binder for composite wood products, agricultural by-products such as wheat straw, rice hulls and sugar bagasse, producing high performance board products. They quoted a delivered price of approximately US$0.85 per pound or C$1.27 per pound.

2. Dow Polyurethanes

Dow's Polyurethanes Division is located in Freeport, Texas. The parent company, Dow Chemical Company, is a global science and technology company that develops and manufactures a portfolio of chemical, plastic and agricultural products and services for customers in 168 countries around the world.

Dow's Polyurethanes' MDI(ISOBIND) binder is used in a variety of products to produce composite wood and agri-fibre board products made from agricultural by-products. Dow is a shareholder in the Isobord plant at Elie, Manitoba. Dow would not quote a resin price.

3. Bayer Polyurethane Division

Bayer Corporation's Polyurethanes Division is located in Pittsburgh, PA, and houses the Bayer Global Wood Products R & D Centre. Bayer supplies the North American wood industry with polyurethane raw materials used to manufacture a wide variety of composite wood products, including oriented strand board, engineered wood and agrifibre products. Their polymeric methylene diisocyanate (pMDI) is used as a binder in the production of these composite wood and agrifibre products.

Bayer has nearly completed more than $1.3 billion in capital investments at its Baytown facility. The investments primarily cover three major projects to expand production capacities of two components used in the production of polyurethane diphenylmethane diisocyanate (MDI), toluene diisocyanate (TDI) and raw materials for TDI as well as capacity for Bayer's Makrolon® polycarbonate. This program, which focuses particularly on strengthening Bayer's plastic and polyurethane businesses, is the largest single investment in the Bayer Group's 135-year history and

is part of Bayer's ongoing plans to invest $9 billion in its U.S. operations by the year 2000. Bayer's declined to quote a resin price.

D. Other Considerations

In addition to the manufacturing process, straw panelboard plants share common requirements in site layout and general operations that influence capital and operating spending and plant safety. The following list highlights some of the important non-processing areas that have to be addressed when planning a plant.

- **Environmental Study** – An environmental study will be required with respect to air pollution and water contamination. Particular requirements can be obtained from Saskatchewan Environment and Resource Management.

- **Ventilation and Safety** – Slight negative ventilation is required for the manufacturing process. MDI fumes must be captured from all exposed mat areas and from all equipment containing MDI. These fumes must not be ventilated into the air but placed into a piece of equipment where they will be reacted. Also, MDI is classified as a hazardous material and staff must be trained according to the hazardous materials regulations.

- **Boiler** – Consideration should be given to use of dual fuel boiler. Waste dust can be used to fuel the boiler at a substantial saving to using natural gas. The boiler can also be designed to provide hot water heat for the building.

- **Safety Training Straw Storage** - The straw storage area requires a layout design to accommodate the required the annual production capacity of the production unit plus 20% of safety stock. The large square bales can be stacked approximately four tiers high. Higher than four tiers, risks creating crushing failure on the bottom row due to excessive weight. Width and length of stacks should be predetermined. Adequate distance between stacks is essential to reduce the risk of rapid escalation of fire should that misfortune occur.

- **Security and Lighting** - The facility shall be properly secured with chain link fencing and powered gates to eliminate the risk of vandalism and risk of fire. Proper yard lighting is essential, as the plant should operate around the clock.

- **Water Supply** – An adequate water supply, whether from a local municipal source or a well, is essential. The water is required by the production unit, for domestic consumption and is critical for fire protection both for the plant sprinkler system and yard hydrants.

- **Fire Protection** – Fire regulations require sprinkler system within the plant and also yard hydrants. A full year's inventory of straw may be stored on-site and for both financial and safety reasons a detailed emergency response plan must be in place.

- **Rodent Control** - In order to protect the quality of the straw and to eliminate the presence of rodents prior to straw breaking and hammer milling, it is necessary to establish several control stations in the straw storage areas and within the plant itself.

- **Yard Drainage** - Appropriate yard drainage is essential to protect the straw inventory. Adequate ditching and water disbursement mechanisms must be designed into the yard layout, taking into consideration yard elevations and slope. Also the ground must be prepared to prevent straw from freezing to the ground in winter. Laying a bed of straw under the rows of bales often does this.

- **Yard Equipment** - Telescopic loaders with articulated steering perform the bale unloading and stacking activities. Also, drive-on scales are required for straw weighing and delivery recording and probe moisture testers are used to determine bale moisture levels and straw quality.

- **Straw Quality Assurance Inspections** - Regular planned farm field inspections of straw are required during growing season and during the harvest and baling period. Proper recording systems must be established for monitoring straw quality, ownership identity and other pertinent information with respect to the straw delivery and farmer reimbursement.

- **Straw Baling and Hauling** – These activities can be contracted to a third party company created to provide quality raw materials (straw) to the production plant. This third party could be responsible for sourcing, purchasing, baling and delivering the straw to the plant gate. Another option would be to have the local farmers set up a co-operative or a farmer controlled organization to provide the straw to the plant at a predetermined price.

- **Plant Location** – The plant should be located in an area with a sufficient cereal straw supply and it have access to rail as this is the most efficient means for transporting bulky and heavy products such as particleboard.

E. Selecting a Plant Supplier

The process for selecting a plant supplier (the equipment will come from a number of manufacturers and suppliers) starts with the development of a Request for Proposal

(RFP). Based on the results of the marketing and business plans, this RFP would describe in detail:

- Required annual plant output capacity by product type and any longer term expansion plans
- Product specifications and grades of the particleboard and other products to be manufactured
- Required dimensional board sizes for the finished product
- Raw materials to be used (type of agri-fibre, resin, etc.) and storage requirements
- Description of energy and water supplies
- Site description and regulatory requirements (environment, labour, fire, etc.)
- Finished product packaging, storage and shipping requirements
- And other pertinent information about the project, such as warranty expectations, project's timelines, other contracted (e.g. engineering services), etc.

Plant suppliers are invited to respond to the RFP. Interested suppliers will come back with proposals containing descriptions and recommendations regarding the equipment to be used and they should provide a complete design of the manufacturing process. They should also address a host of critical project issues such as equipment installation, electrical and mechanical requirements, engineering support and specification for the building. They should also provide detailed site requirements (storage, water requirement, power, etc.). Proposals should contain a comprehensive budget quotation that addresses all of the equipment and installation costs, including taxes, import duties and transportation costs, and it should include a list of items and services that the client is responsible to provide. Potential suppliers should also provide documentation supporting why they believe their particular equipment and manufacturing process solution is the best one for the particular project.

It is critical that the RFP demands guarantees from each supplier that their design, equipment and manufacturing process recommendations will meet all of the product specifications and output capacities contained in the RFP. There should be substantial penalties in the successful plant supplier's contract for non-performance and for any delays they are responsible for in plant commissioning.

The project proponent should hire a project manager to lead the preparation of the RFP and direct the proposal evaluation and supplier selection process. Typically, the final

selection decision is made by project's Board of Director or plant owner based on the recommendations of the project manager. For obvious reasons, the project manager should not be a potential equipment supplier or working for anyone else selling equipment or services to the project. The project manager must have experience in panelboard plant design and manufacturing in order to oversee the equipment installation and plant commissioning and to ensure the supplier fulfills all of the conditions and guarantees contained in the contract. In addition to the project manager, the project proponents will likely have to retain engineering expertise to oversee site development and manage building contractors and other suppliers, and also accounting and legal advisors.

IV

Capital Cost Projections

Capital cost projections have been assembled for plants of three different production capacities of straw particleboard (Exhibit IV-1). The small-scale plant has annual production capacities of 10,200 and 20,400 M^3 for one and two lines of production, respectively. The mid-scale plants have six to seven times the output capacity of the small-scale plant. The first plant is based on a capital cost quotation for a single production line of 63,000 M^3, annually. The second plant included quotations for one and two production lines. The large-scale plant is based on a continuous process line that is 12 times more productive than the two-line, small-scale plant. A capital cost quotation was not received for the large-scale plant. The costs were estimated based on input from a variety of industry sources and business plans.

The small-scale plant profiled in the analysis only manufactures a lower quality, homogeneous particleboard that commands a lower market price than higher quality, layered particleboard produced by the other three plants in the analysis. The small-scale board only meets M-1, M-2 and underlay standards, while the others manufacture the M-3 board used by furniture manufacturers.

The capital budget estimates for the four plants are provided in Exhibit IV-1. The assumptions used to develop the capital budgets follow the exhibit.

Our capital cost analysis had the following results:

1. It is estimated a small-scale plant with two production lines can be built for about $15 million, including working capital. The estimate for a medium-scale plant with two lines is about $57 million in capital, and a single line plant is expected to cost somewhere between $37 million and $41 million. The large-scale plant budget is predicted at $189 million. Isobord had an initial budget of about $150 million, but industry insiders report the final cost was in the order of $213 million due to changes in process design and the need to upgrade and add equipment.

2. While the small-scale plant with its two-lines is about ¼ of the capital cost of the medium-scale plant and 1/12 of the large-scale plant it does not yield the lowest investment per unit of output. The medium-scale plant with two production lines has by far the lowest capital cost per M^3, assuming all the

plants are operating at full capacity. At C$391 per M^3, the investment per unit of output is 47% lower than the two-line, small-scale plant ($719) and 53% less than the large-scale plant ($823).

3. Adding a second line to the medium-scale plant increases the capital budget by 53%, but it doubles the output capacity. This scale advantage causes the investment per unit of output to drop by 23% from $507 to $389 per M^3.

It is clear from this analysis that the two-line, medium scale plant is the optimal size in terms of capital investment per unit of output. The next chapter also concludes it is the most advantageous manufacturing size in terms of average production cost per unit of output.

Exhibit IV-1: Estimated Capital Costs by Production Scale

	Small-Scale		Medium-Scale			Large-Scale
ANSI Standard	Underlay, M-1, M-2		M-3			M-3
Production Lines	1-Line	2-Line	1-Line	1-Line	2-Line	Continuous
Capacity M^3 / Year	10,200	20,400	63,000	73,100	146,200	230,000
Capacity 1000 Sq.Ft. / Year	5,763	11,527	35,597	41,303	82,608	129,957
Building and Equipment						
Land	$52,000	$65,000	$104,000	$104,000	$130,000	$260,000
Site Preparation & Straw Storage	275,000	280,000	650,000	650,000	660,000	1,200,000
Steel Building & Foundation	800,000	1,000,000	3,600,000	3,600,000	5,400,000	12,600,000
Machinery and Equipment	5,670,000	9,000,000	26,369,863	20,942,397	33,241,900	132,967,600
Installation, Mechanical, Electrical	515,000	525,000	2,191,780	3,725,000	5,960,000	12,000,000
Loaders, Forklifts, Skid Loaders, etc.	195,000	195,000	250,000	250,000	350,000	2,500,000
Truck Scale	45,000	45,000	90,000	90,000	90,000	90,000
Spare Parts Inventory	10,000	15,000	300,000	300,000	500,000	1,000,000
Commissioning, Training, etc.	300,000	300,000	400,000	400,000	447,000	1,000,000
Contingency 8%	628,960	914,000	2,716,451	2,404,912	3,742,312	13,089,408
	$8,490,960	$12,339,000	$36,672,094	$32,466,309	$50,521,212	$176,707,008
Project Costs						
Management Team	$200,000	$200,000	$400,000	$400,000	$400,000	$750,000
Office Space	23,100	23,100	23,100	23,100	23,100	50,000
Project Management & Engineering	200,000	200,000	300,000	300,000	400,000	2,000,000
Business/Marketing Plan	75,000	75,000	200,000	200,000	200,000	300,000
Legal	100,000	100,000	150,000	150,000	150,000	250,000
Accounting	25,000	25,000	50,000	50,000	50,000	100,000
Office Systems	100,000	100,000	150,000	150,000	150,000	300,000
Regulatory/Permit Fees	15,000	15,000	15,000	15,000	15,000	30,000
Straw Inventory @$40/t)	120,000	240,000	910,000	910,000	1,820,000	2,800,000
Contingency 5%	42,905	48,905	109,905	109,905	160,405	329,000
Financing Fees (3.25%)	305,239	434,395	1,000,000	1,000,000	1,000,000	1,500,000
Interest (2 months @ 10.5%)	82,196	116,976	341,144	304,336	471,629	1,606,961
Working Capital	750,000	750,000	1,000,000	1,000,000	1,500,000	2,500,000
	$2,038,440	$2,328,376	$4,649,149	$4,612,341	$6,340,134	$12,515,961
Total Capital Budget	$10,529,400	$14,667,376	$41,321,244	$37,078,650	$56,861,346	$189,222,969
Capital Cost per M^3	$1,032	$719	$656	$507	$389	$823
Capital Cost per 1000 sq. ft.	$1,827	$1,272	$1,161	$898	$688	$1,456

Source: Assembled by consulting team

A. Capital Budget Assumptions

All of the items in the capital cost budgets are only approximations. They were developed with the help of various equipment suppliers and straw particleboard manufacturers. Also, a number of business plans for straw particleboard plants were reviewed. More precise

budget projections would entail the development of a detailed building and equipment built around specific product standards and output capacity.

- **Land** size must accommodate the building, yard access and on-site straw storage requirements with proper drainage and fire lanes. The site should have access to rail and highway for shipping and raw material transport. Rail is the most economical transportation for shipping panelboard products to distant markets. The small-scale plant is assumed to be located on an 80 acre green field site for the first line and 100 acres for two-lines. The medium-scale plant ideally requires a 1/4 section for one-line and 200 acres for two-lines. A large-scale continuous production plant should have at least 400 acres in order to house up to 200,000 square bales of straw. A square bale (4ft. by 4ft. by 8ft.) weighs approximately 1,100 pounds and is the most efficient bale size for storage and handling. The Isobord plant at Elie, Manitoba is situated on only 68 acres, but they maintain three additional sites for straw storage. This budget uses an average cost of $650 per acre.

- **Site Preparation** includes leveling, drainage, surfacing, road access, fencing, water supply and fire protection hydrants, natural gas and electrical services, and yard lighting. Fire protection requires 1,200 gallons per minute for two hours. Manufacturing requires water for the process. There can be a wide variance in these costs depending on the access to utilities.

- **Building and Foundation** includes building piles, cement floors and a steel or cement block building. The building costs were calculated at $60 per sq. ft. for the medium-scale and large-scale plants. The small-scale plant was based on $40 per sq. ft. because the foundation work is less extensive due to lighter and small equipment. The small-scale building is 20,000 and 25,000 sq. ft. for one and two-lines, respectively. The medium-scale plant is assumed to be 60,000 and 90,000 sq. ft. for one and two-lines, respectively. The large-scale continuous production building cost is based on 210,000 sq. ft. In each case, twenty-five percent of the building space is set aside for storage of finished product.

- **Machinery and Equipment** estimate is a turnkey cost estimate that is all inclusive including fibre storage, boilers, conveyers, resin blenders, press, sander and cutting station, cooling racks and so on. This budget also includes programmable logic controls, spare parts, freight and equipment import duties.

- **Installation, Electrical and Mechanical** take care of all labour and supplies associated with equipment installation, electrical motors and systems and mechanical connections.

- **Loaders, Skid Loaders and Forklifts** are need to handle and move raw materials (straw, resin, etc.) and finished products.

- **Truck Scale** is required for straw weighing and payments to farmers and transporters. The scale for the small-scale plant is portable.

- **Spare Parts Inventory** is for weekly scheduled maintenance and emergency repairs to minimize production down time.

- **Commissioning and Training** involves plant startup, product testing and employee training.

- **Contingency** has been established at 8% to cover unforeseen costs and construction delays. The size of the contingency depends on the level of effort that has been taken in developing the capital budget. In this case, a higher contingency fee could be justified.

- **Management Team** members need to be hired at different stage of the project. Early in the project the CEO and CFO are required to negotiate financing terms and conditions, oversee design and tendering, retain engineering and other professional service and to protect the interests of the shareholders. In these budget projections, the CEO is hired two years before startup and the CFO is hired one year before startups in order to monitor project costs and develop costing systems. The plant supervisor and maintenance staff is on-site when the equipment is being installed. The production staff needs to be hired prior to commissioning.

- **Office Space** is required to house the management team during the project planning and construction phases. It is assumed that 2,200 sq. ft. of office space is leased at an annual cost of $10.50 per sq. ft.

- **Project Management** is for hiring a project manager with the engineering and technical skills to direct the selection of suppliers, monitor plant construction, and oversee equipment installation and plant commissioning. These costs also include the contracting engineering, architectural and other professional services as required.

- **Legal** involves corporate structure, shareholder agreements, financing documents and legal dealings with agencies such as securities commission.

- **Accounting** covers the annual audit, systems set-up and tax and corporate finance advice.

- **Office Systems** is for the purchase of administrative and accounting systems.

- **Business/Marketing Plan** is required to attract project financing and ensure the project has a sound organizational structure and financial foundation. The financials in the business plan should be audited.

- **Straw Inventory** for plant commissioning the plant is based on 35% of annual production requirements. Production inventory is included in operating costs.

- **Financing Fees** are estimated to be 3.5% based on 1.5% for long-term debt and 5% for equity. A cap of $1.5 million has been placed on these fees. It is assumed that 50% of the financing is equity and 50% is debt.

- **Startup Interest** is based on two months of interest payments for long-term debt at an annual rate of 10.5%.

- **Working Capital** has been assigned to ensure adequate cash flow once the plant is in operation. There are no interest charged for working capital during the construction and commissioning phases. It is assumed the working capital would not be drawn on until after the plant is in production.

V.

Operating Budgets

Operating cost estimates were in part obtained from quotations from suppliers and also from various business plans and other studies. Exhibit V-1 contains a modified income statement for the three production scales of plants under review. This analysis underscores the following:

1. The analysis shows that only the medium-scale plant provides a return on equity. For the plant with the lowest capital cost and highest production capacities, the return for one-line is an insufficient 3.9% and for two-lines the return jumps a reasonable 20.5%. Even though the output increases 100% by adding a second line, the total production costs increases by only 76%. On a per unit basis, this means the production cost drops by 12% from $211 to $186 per M^3.

2. The large-scale plant in this analysis shows an annual operating loss of $12.5 million, largely due to an annual depreciation cost of $18.3 million. Although the large-scale plant costs more than three times the medium-scale plant with two-lines, it offers a production output that is only 1.6 times larger. What is more troubling is the total variable and fixed production costs almost double over the medium-scale plan for this 1.6 times gain in output.

3. Surprisingly, the small-scale plant is no more profitable with two-lines than it is with one-line. This is because the second line operates at breakeven. Due to the lower price paid for underlay, M-1 and M-2 particleboard, a doubling of the quantity of board made only generates incremental revenues that are roughly equivalent to the increase in total manufacturing costs.

The assumptions used in developing the production analysis come after Exhibit V-1.

Exhibit V-1: Estimated Return on Equity by Production Scale

	Small-Scale		Medium-Scale			Large-Scale
ANSI Standard	Underlay, M-1, M-2		M-3			M-3
Production Lines	1-Line	2-line	1-Line	1-Line	2-line	Continuous
Capital Budget	10,529,400	14,667,376	$41,321,244	$37,078,650	$56,861,346	$189,222,969
Debt/Equity Ratio (1:1)	$5,264,700	$7,333,688	$20,660,622	$18,539,325	$28,430,673	$94,611,485
Capacity M^3 / Year	10,200	20,400	63,000	73,100	146,200	230,000
Capacity 1000 Sq.Ft. / Year	5,670	11,340	35,597	40,630	81,260	127,835
Finished Board Output (tonnes)	6,835	13,670	42,210	48,977	97,954	154,105
Straw Consumption (tonnes)	8,200	16,400	50,652	58,772	117,545	184,926
Variable Costs						
Straw	$328,000	$656,000	$2,026,080	$2,350,896	$4,701,792	$7,397,040
MDI Resin	443,592	887,183	3,287,315	3,814,329	7,628,658	16,002,263
Release Agent	33,608	67,215	207,547	240,820	481,640	757,734
Maintenance, Parts and Consun	81,600	163,200	704,340	817,258	1,634,516	2,571,400
Fixed Variable Costs						
Plant Labour	858,000	1,144,000	1,300,000	988,000	1,248,000	2,326,500
Other Salaries & Benefits	190,000	190,000	320,000	320,000	360,000	400,000
Professional Fees	15,000	15,000	25,000	25,000	25,000	40,000
Office Expenses	10,000	10,000	24,000	24,000	24,000	24,000
Marketing (3.5% of sales)	54,574	109,148	500,850	571,664	1,143,328	1,798,638
Electrical Consumtpion	125,000	180,000	378,040	431,491	862,981	1,357,608
Natural Gas Consumption	30,000	51,000	300,000	5,000	10,000	1,840,000
Insurance	25,000	25,000	42,716	48,756	97,512	153,402
Miscellaneous and Packaging	28,350	56,700	177,985	203,150	406,300	639,175
Fixed Costs						
Depreciation	956,597	1,354,801	3,873,410	3,452,832	5,376,822	18,276,501
Debt Interest	552,793	770,037	2,169,365	1,946,629	2,985,221	9,934,206
Working Capital Interest	78,750	78,750	105,000	105,000	157,500	262,500
Property Tax	25,000	25,000	80,000	80,000	80,000	100,000
Total Production Cost	$3,835,863	$5,783,034	$15,521,648	$15,424,824	$27,223,270	$63,880,967
Production Cost per M^3	$376	$283	$246	$211	$186	$278
Production Cost per 1000 sq. ft	$677	$510	$436	$380	$335	$500
Revenue per 1000 sq.ft.	$275	$275	$402	$402	$402	$402
Projected Total Revenue	$1,559,250	$3,118,500	$14,309,994	$16,333,260	$32,666,520	$51,389,670
Gross Profit/Loss	-$2,276,613	-$2,664,534	-$1,211,654	$908,436	$5,443,250	-$12,491,297
Income Tax (22%)				-$181,687	-$1,088,650	
After Tax Profit/Loss	-$2,276,613	-$2,664,534	-$1,211,654	$726,749	$4,354,600	-$12,491,297
Equity Investment	$5,264,700	$7,333,688	$20,660,622	$18,539,325	$28,430,673	$94,611,485
Return on Equity				3.9%	20.5%	

Source: Estimates assembled by consulting team

A. Operating Cost Assumptions

This analysis assumes that each of the plants are operating at full capacity and that the entire production is sold at current market prices. The medium-scale and large-scale plants satisfy the high-value M-3 particleboard standard used in the furniture and cabinetry markets. The small-scale plant can only produce M-1 and M-2 standard boards used in the medium-value flooring market and wall sheathing markets.

- **Production Capacity** for all of the plants in the analysis is based on a standard 340 days per year and 22 hours per day. The remaining down time is for scheduled maintenance and cleaning and an annual overhaul of equipment.

- **Straw Costs** of $40 per tonne assumes $15 per tonne for the farmer, $15 a tonne for baling and stacking and $10 per tonne for transportation. Every tonne of finished board produced requires 1.2 tonnes of straw for the manufacturing process.

- **MDI** resin has a current market price of C$1.18 per pound. Based on current performance in straw particleboard plants, it is assumed that resin consumption is 2.5% of the weight of the finished product for the small-scale plant. The small-scale plant uses the least resin because the quality of the particleboard is built to lower M-1 and M-2 ANSI standards. The medium-scale plant requires 3.0% resin based on the usage rate reported by the plant in Whapeton, North Dakota. For the continuous production process, the resin usage is assumed to be 4%, even though the Isobord plant is reported to have had usage rates over 6%.

- **Release Agent** is applied to prevent the particleboard from adhering to the press plates and mat forms. The release agent cost is C$4.92 per tonne of finished board.

- **Maintenance, Parts and Consumables** relate to scheduled bi-weekly maintenance and the annual shut down, oil and grease consumption and consumables, which includes items such as saw blades, sanding belts, sharpening stones, dust filters, etc. The cost is estimated at $11.18 per M^3 of finished product for the two larger plants and $8.00 per M^3 for the small-scale plant.

- **Plant Labour** has been calculated at annual an average wage of $26,000, including payroll and benefit costs. Using three shifts per day, the small-scale plant would have a production work force of 33 for one-line and a total of 44 plant staff for two-lines. The medium-scale plant employs 38 on the first line and 10 additional employees for the second line for a total of 48 production staff for two-lines. The continuous production plant requires 98 production staff.

- **Other Salaries** are for three office staff, laboratory technician, the plant manager, CEO and CFO. For the small-scale plant there is only one and one-half office staff positions. Salary estimates have been scaled to the size of the plant.

- **Professional Fees** are for legal, accounting and other outside professional services.

- **Office Expenses** are for telecommunications, internet access, courier, copying and a host of other expenses.

- **Marketing** cost was calculated at 3.5% of sales based on brokers' charges in the composite panel industry. It is assumed that the plant will not have its own market department but will use brokers and other third-party distributors. To establish a marketing department, the annual cost is likely to be 3 to 4% of sales. A new market entrant requires a large marketing budget during the first several years of operation until the product becomes established in the marketplace.

- **Utilities** are based on a combination of actual cost data and project energy consumption for plants of these operating sizes. The electrical rate used was $0.055 per kilowatt-hour. The medium-scale plant is based on a design that burns dust particles in its boiler and therefore has minimal natural gas consumption.

- **Insurance** has been based on a cost of $0.0012 for every foot of finished board produced.

- **Miscellaneous and Packaging** covers strapping for finished product, shrink wrapping and miscellaneous supplies have been estimated at $5 per 1000 sq. ft.

- **Depreciation** is based on 10 years straight line for equipment and 20 years for the building. Development costs were depreciated over five years.

- **Debt Interest** is based on 50% debt financing of the project at an annual interest rate of 10.5%.

- **Property Tax** reflects the current levy being charged commercial operations in the Municipality of Sherwood adjacent to Regina.

- **Board Selling Price** is C$402.00 (FOB plant) per thousand sq. ft. and is based on current market information obtained from straw particleboard manufacturers for high quality M-3 standard board and from pricing information published by Panel Source International. The C$275 per thousand sq. ft. for the small-scale plant is a blended price for M-1 and M-2 particleboard and underlay.